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(54) Checking the state or condition of a hydraulic fluid

(57) For the purpose of determining and checking the state or condition of hydraulic fluid in, for instance, a vehicle brake system, the boiling point or a characteristic value of the fluid which depends on the boiling point, on the one hand, and the momentary or current temperature of the fluid, on the other hand, are measured by means of sensor element(s) (13). By comparing the two measured values a so-called thermal reserve is determined which constitutes a measure for the further permissible heating of the fluid. As shown a single resistive detector (13) can be operated in a heated mode to provide a value corresponding to the boiling point (which value is stored in memory (15)) and an unheated mode to provide a current temperature value. When the difference between these falls below the level of a reference source 18, a warning signal is released, indicating that a minimum value of thermal reserve has been reached. An alternative system (Fig. 3 not shown, has separate hot and cold sensors. A number of designs of heated sensor element are suggested (Fig. 1 not shown) with open, pierced walls and designed to ensure that, after heating-up, there comes about a stable cellular convection in a temperature range lying below the boiling temperature, which cellular convection is evaluable as indicating the condition of the fluid.

Fig. 2

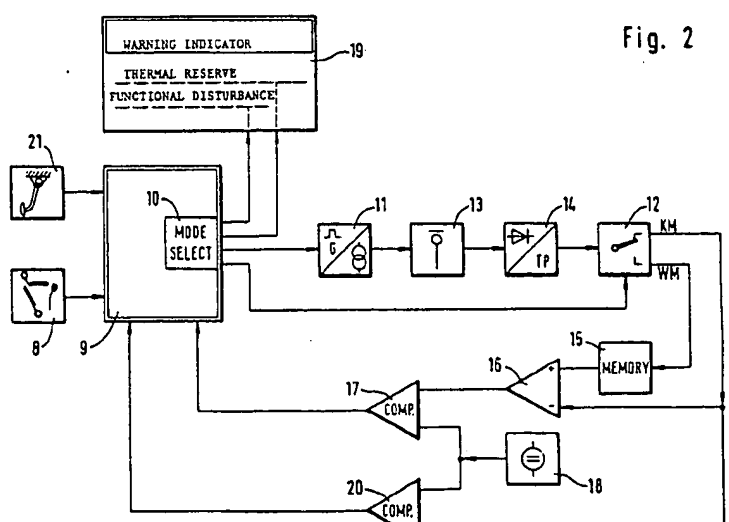

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Fig. 1a

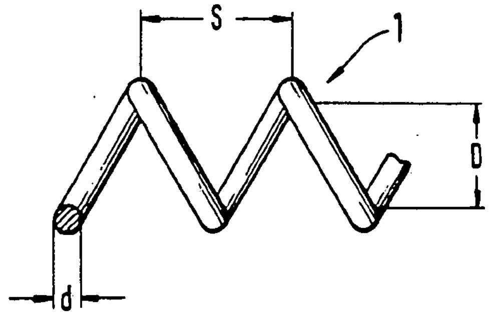


Fig. 1b

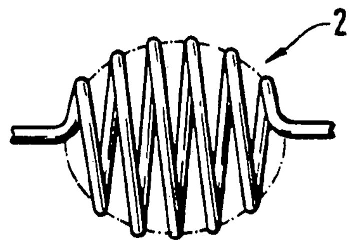


Fig. 1c

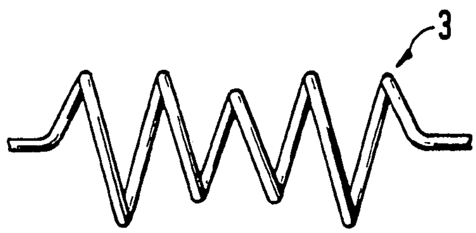


Fig. 1d

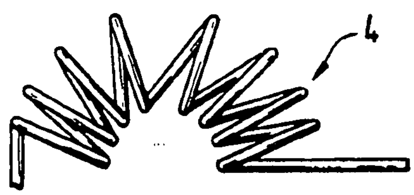
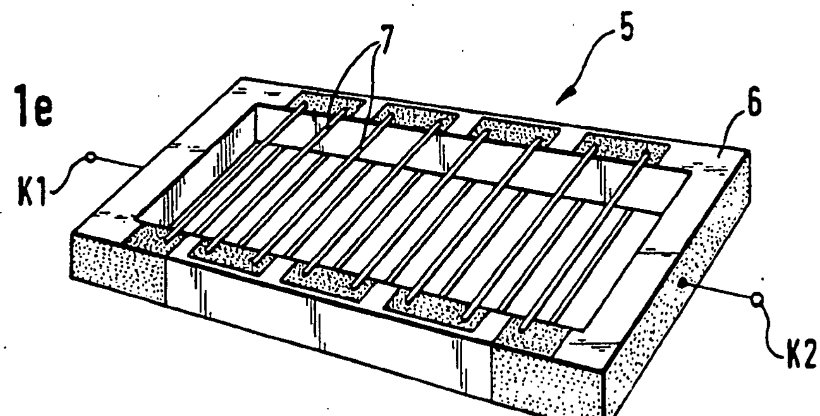


Fig. 1e



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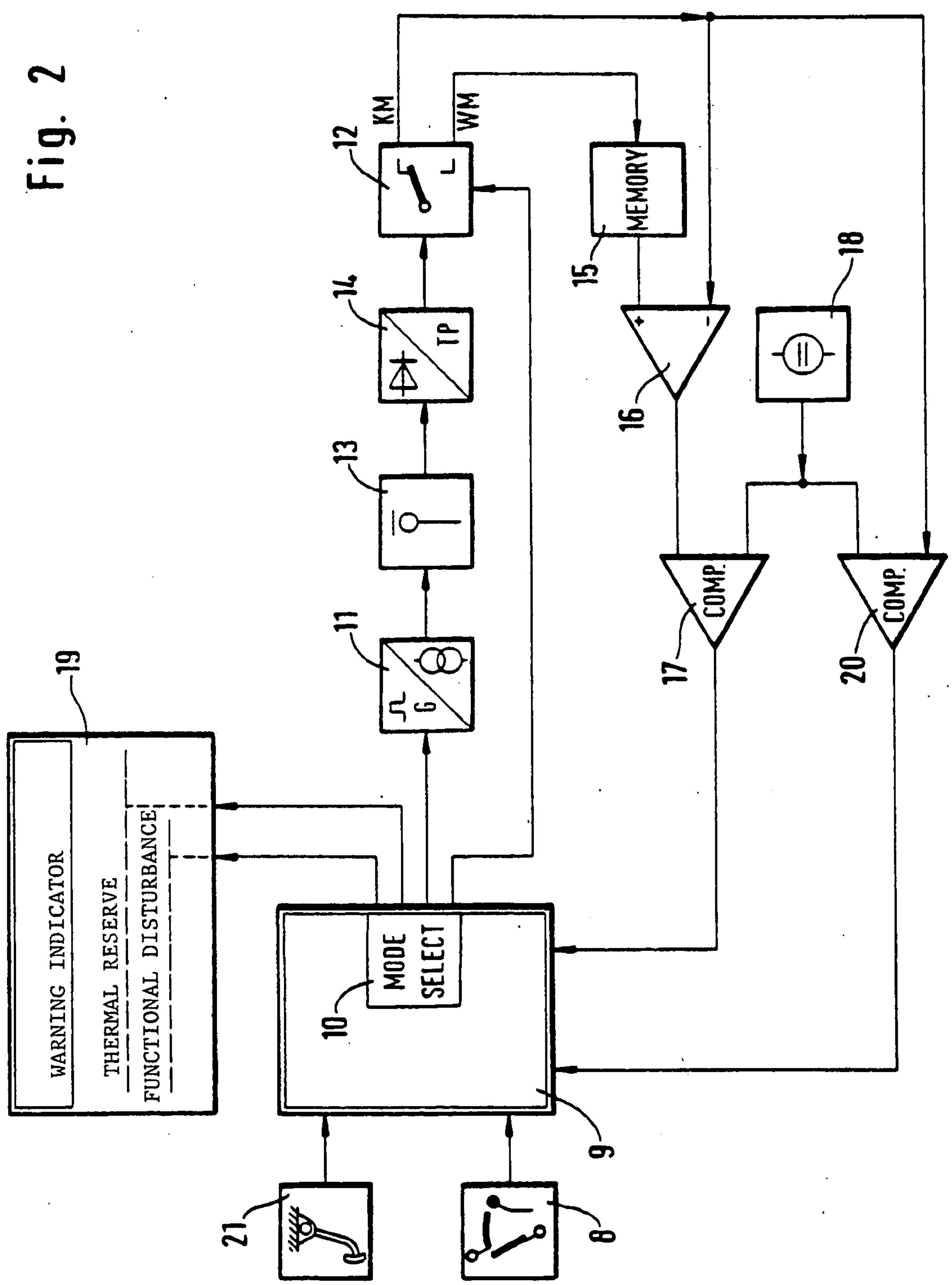
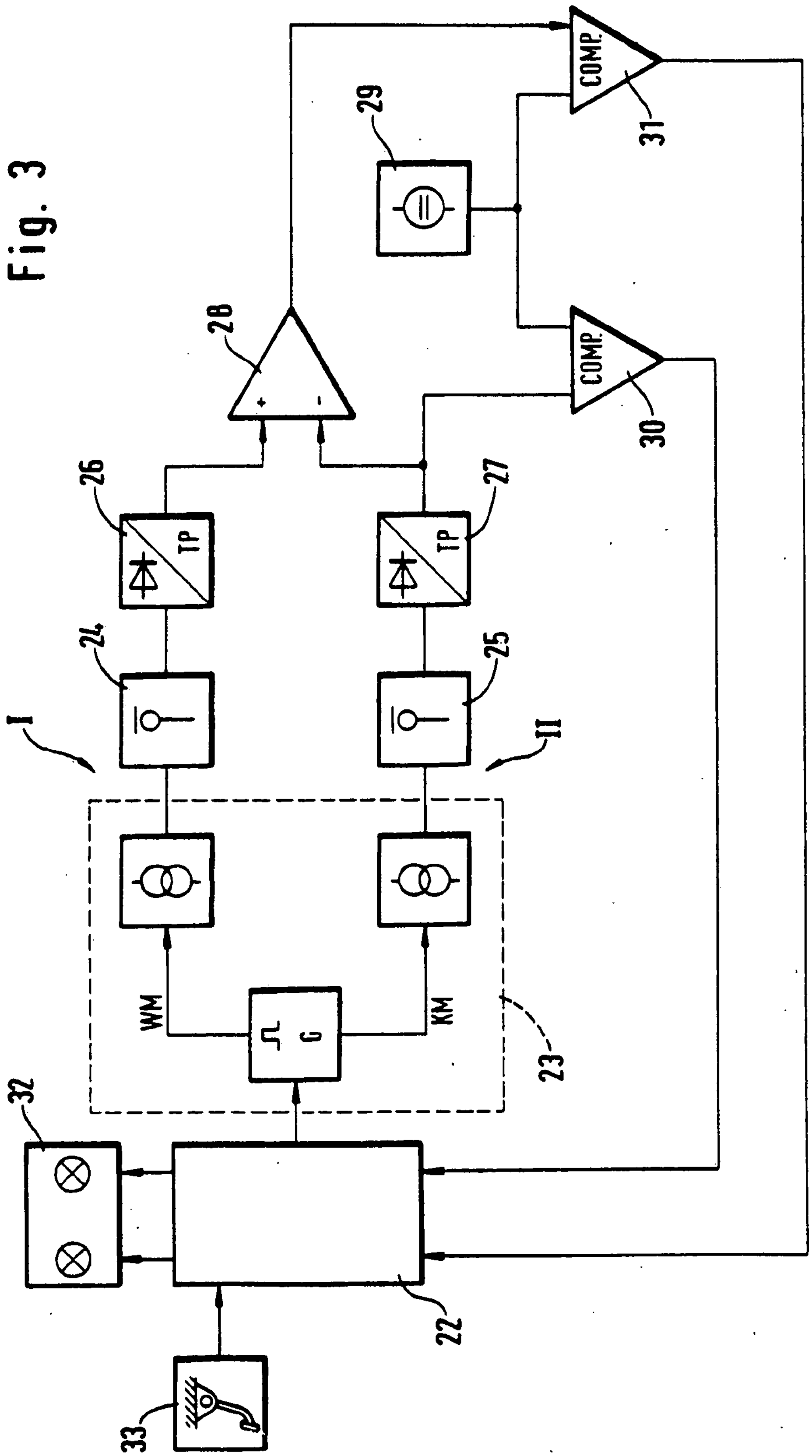


Fig. 2

Fig. 3



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CHECKING THE STATE OF CONDITION OF A HYDRAULIC FLUID

This invention relates to a method and means for determining and/or checking the state or the condition of a fluid contained in a hydraulic system such as a hygroscopic brake fluid, in which the boiling point, or a characteristic value of the fluid depending on the boiling point, is determined by means of sensor elements. Included in this invention are a device for implementing this method and a circuit configuration for controlling this device.

It is already known to check the state of a hydraulic fluid, namely a hygroscopic brake fluid, by measuring the boiling point. Due to the unavoidable absorption of water, the boilling point drops in the course of time so much that, in the case of a strong strain on the brakes and of the brake fluid's heating induced thereby, there may be a formation of vapour bubbles endangering the operativeness of the brake.

The exchange of brake fluid after one or two years as recommended nowadays is not an optimal solution as the process of aging, in particular the absorption of water and the lowering of the boiling point caused thereby, depends on numerous parameters such as the climate, air

humidity, mode of operation, and condition of the brake system and thus varies within very wide limits. Further, even a fresh brake fluid does not offer any safeguards against the fact that in the case of a strong strain on the brakes, such as a prolonged or wild downhill drive in the mountains the temperature of the brake fluid will remain under a value where the dangerous formation of vapour bubbles cannot occur.

Methods and devices for measuring the boiling temperature of a brake fluid in the workshop or in laboratories are likewise known. According to a German industrial standard, a relatively accurate measuring method is known which, can however only be implemented by trained staff with a relatively great expenditure of time and with expensive equipment.

In the European Patent Specifications Nos. 56424 and 74415, measuring methods and measuring probes are described which are immersed in the fluid to be examined and which are designed to heat up a small amount of the fluid and to ascertain the temperature at the onset of boiling. There are doubts as to whether it is possible to determine the boiling point of a brake fluid with sufficient accuracy in this manner, inter alia, because, in fact, only the temperature of the pertaining heating element can be determined, but not the boiling temperature of the fluid.

For determining the condition and the state of a hydraulic fluid it has already been

proposed, according to German Patent Application No. P 3522774.5 (= DE-OS 3522774), to design and heat up a sensor element in such a way as to ensure that there comes about a stable cellular convection in a temperature range lying below the boiling temperature of the fluid. The temperature which in this phase is measured directly or indirectly - namely as a voltage drop above the sensor element - is suitable as a criterion of the boiling point of the fluid to be examined and allows a relatively accurate determination of the boiling temperature.

Also known from German Published Patent Application (=DE-OS) No. 3317638 is a stationary device for checking the brake fluid which is built into the brake system. According to this Published Patent Application, the actual detector can be designed as a component of a bleeder screw.

It is an object of the present invention to overcome the disadvantages of known methods and devices and to provide a method for checking the state or condition of a hydraulic fluid, in particular of a hygroscopic brake fluid, by means of which it is possible to recognise with a high degree of reliability and in time when proper functioning can no longer be ensured due to the momentary state or due to the condition of the hydraulic fluid contained in a hydraulic system. For instance, by means of such a method it must be possible to recognise when, due to thermal stress, the temperature of the fluid in a hydraulic brake system is approaching the boiling point

of the fluid too closely.

According to the invention there is provided a method for determining and/or checking the state or the condition of a fluid contained in a hydraulic system, in which method the boiling point, or a characteristic value depending on the boiling point, is determined by means of sensor elements, characterised in that the momentary state and/or the momentary stress on the fluid is measured and compared with the characteristic value, a so-called (momentary) thermal reserve is thence determined which constitutes a measure for the further stressability, in particular for the permissible further heating, of the fluid and in that the reaching of a predetermined minimum value of the thermal reserve is indicated.

This invention is thus based on the consideration that the boiling point of the fluid depending on the aging, on the one hand, and the momentary thermal stress, on the other hand, must be taken into consideration for assessing the state and the condition or the usability of a fluid. In contrast to a mere determination of the boiling point of the hydraulic fluid, thanks to the determination of the momentary "thermal reserve" it is namely possible to recognise reliably - for instance, in a brake system - whether under the prevailing conditions, i.e., the boiling point of the (aged) brake fluid and the thermal stress on the fluid caused by the braking operation, there exists the danger of the formation of

vapour bubbles and, hence, of an impairment of the brake's operation. Not only is the need for brake fluid exchange pointed out to the driver in time, but there is also an indication of any possible danger due to overstress of the brake and heating-up of the brake fluid which also may happen with fresh brake fluid. The driver then can make allowance for this fact by changing his driving behaviour.

In one advantageous embodiment of the invention, at predetermined intervals, the characteristic value depending on the boiling temperature of the fluid is determined, stored in a memory, and compared with the last-stored characteristic value so as to determine the thermal reserve. For checking a brake fluid in a vehicle brake system it may be expedient to determine and store the characteristic value by means of a measuring device stationed in the vehicle, when the engine is started, the measuring device consisting essentially of sensor elements and electronic circuits for evaluating the sensor signals. Upon the application of the brake, the stored characteristic value is compared with the momentary brake fluid's temperature so as to form the thermal reserve.

Another embodiment of the invention provides that, during a braking operation, the characteristic value and the momentary temperature of the brake fluid are measured alternatingly by means of a measuring device stationed in the vehicle, and that, for forming the thermal reserve,

the measured values are compared.

One device for implementing this method essentially comprises of a measuring device for determining the boiling temperature of the fluid, or a characteristic value depending on the boiling temperature, temperature-measuring elements for determining the momentary temperature of the fluid, circuits for handling and processing the measured signals as well as for storing the characteristic values determined last and for determining a momentary thermal reserve derived from the difference of the measured values, and indicating units for signalling a sufficient and/or an insufficient thermal reserve.

The measuring device for determining the characteristic value may be equipped with one or more sensor elements arranged in the fluid. In doing so, for determining the characteristic value it is expedient to design the sensor elements so as to be capable of being heated up.

The determination of the boiling temperature or of a characteristic value depending on the boiling temperature is essential to the method and device of this invention. According to one embodiment, the boiling temperature, or the characteristic value is determined by means of a sensor element having a hollow space with open, pierced walls and so designed as to ensure that, after heating up to a temperature range lying below the boiling temperature, there is established a stable cellular

convection evaluable as a criterion of the condition and/or the state of the fluid. The sensor element can be designed in the form of a hollow coil, a perforated tube, a hollow body limited by grid-or-net-shaped boundary surfaces, or the like. The momentary temperature of the fluid can be determined by measuring the temperature-dependent electrical resistance of such a sensor element.

Heat-up sensor elements of the above-mentioned kind wherein a stable cellular convection can be achieved are described in the German Published Patent Application No. 3522774.

According to a further embodiment of the invention, the sensor elements for heating up the fluid or for measuring the temperature of the fluid are supplied with alternating current. Thereby it is possible to avoid undesired electrolytic effects in the fluid to be examined.

In the case of a vehicle brake sytem, the sensor elements for determining the momentary temperature and/or the characteristic value depending on the boiling temperature are expediently arranged in the vehicle's brake system in the wheel brake cylinders or in the proximity thereof. On the other hand, it is also possible to arrange the sensor element for determining the momentary temperature in the wheel brake cylinder and to arrange the sensor element for determining the characteristic value in the pressure medium compensation/storage reservoir of the brake system.

According to a further embodiment of the invention the same sensor elements can be used both for determining the boiling temperature, or the characteristic value, and for measuring the momentary temperature.

Upon the starting of the automotive vehicle's engine, a circuit configuration for implementing the method of this invention and for controlling a corresponding device serving for checking the brake fluid contained in a vehicle's brake system measures the boiling temperature of the brake fluid or a corresponding characteristic value and stores the measured result until a new start of the engine, the same sensor element determining the temperature of the fluid during the application of the brake so as to determine the momentary thermal reserve.

Upon the application of the brake pedal, according to another circuit configuration, the boiling temperature, or the characteristic value of the brake fluid, and the momentary temperature of the brake fluid are measured by means of the same sensor elements and the successive values measured are compared so as to form the momentary thermal reserve.

The individual sensor elements in the last-mentioned embodiments are operated in the so-called hot mode, on the one hand, and in the so-called cold mode, on the other hand. In the hot mode, the sensor elements are operated as heating filaments or heating coils or the like and electrically heated up so as to have a cellular

convection come about in the area of the sensor elements and to enable the determination of the boiling point or of a corresponding characteristic value. In the hot mode, too, the boiling temperature or the temperature where there occurs the cellular convection is determined by measuring the electrical temperature-dependent resistance of the sensor element. In the cold mode, the sensor elements are fed a comparitively very low current not effecting any heating-up, but only permitting a measurement of the electrical resistance of the sensor element, which electrical resistance depends on the temperature of the surrounding fluid. Thus, in the cold mode the sensor elements serve as mere temperature-measuring elements.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 shows several variants of sensor elements permitting a cellular convection to be achieved in the hot mode;

Figure 2 is the block diagram of a circuit configuration for implementing a method according to the invention and for operating a corresponding device; and

Figure 3 is a block diagram of another embodiment of the circuit configuration of Figure 2.

Figure 1a shows a particularly simple embodiment of a sensor element for implementing the method and for constructing a device according to this invention. In

this case, the sensor element 1 is a hollow coil which, in this example, is wound from a (90%/10%) platinum-and-iridium wire. The wire diameter "d", for instance, is 50 micrometers, the coil diameter "D" is 200 micrometers and the pitch "S" is 240 micrometers. The entire sensor element - only part thereof being shown in Figure 1a - had 20 windings in one embodiment. The cold resistance, namely the resistance at room temperature, was 2.3 ohms. By means of an alternating current of 700 milliamperes it was possible to heat up the sensor element 1, or rather the hollow coil, until there resulted a cellular convection. While in the heat-up phase the electrical resistance at first rose steeply the formation of a cellular convection was discernible by the transition of the resistance curve into a range of a small, approximately constant gradient. This has been described in detail in the above-mentioned German Published Patent Application (=DE OS) No. 3522774. The amount of the electrical resistance of the hollow coil, or rather of the sensor element 1, in the range of the cellular convection permits with great accuracy conclusions with regard to the boiling temperature of the examined brake fluid and, thus, with regard to the state and condition thereof. Upon a further heating-up beyond the phase of cellular convection it was not possible at reasonable expense to determine any reproducible resistance variation in dependence on the supplied current, which resistance variation could have been evaluated as a

measured value.

Figures 1b, 1c, and 1d show further hollow-coil-shaped or hollow-coil-type configurations 2, 3, and 4 which may be made from the same wire as the sensor element 1 as per Figure 1 and where there likewise results a stable cellular convection near the boiling point of the fluid.

Figure 1e shows an embodiment of a sensor element 5 which can be used instead of the coils shown in Figures 1a to 1d. The sensor element 5 has a frame-shaped supporting body 6 made of ceramics, for instance, and serving as a substrate for a heating filament 7 applied thereto in a meandering-pattern or grid-shaped manner, The sensor element 5 is connected via the terminals k1, k2.

The device essentially comprises one or more sensor elements 1 - 5 represented in Figure 1 and an electronic circuit configuration by means of which preferably alternating current can be supplied to the sensor elements 1 to 5 and by means of which the measured signals can be derived and evaluated. Expediently, sensor elements are arranged in all wheel brake cylinders, in the proximity thereof, or at least in the wheel brakes stressed most. Also suitable for determining the boiling point or the corresponding characteristic value is a sensor element arranged in another spot such as in a pressure medium storage reservoir.

In principle, the boiling point of the fluid, on the one hand, and the momentary thermal stress which in particular depends on the heating-up during a braking operation, on the other hand, are measured and compared with each other by means of the method according to the invention and the corresponding device. A so-called momentary thermal reserve is derived from these measured values. This momentary thermal reserve reveals whether in the case of a further thermal stress, or rather in the case of a further increase in the fluid's temperature, one has to reckon with the formation of vapour bubbles due to the boiling point's being approached and, hence, with the brake's operation being endangered. The thermal reserve is thus a characteristic value signalling that an available residual thermal absorption capacity has been exceeded.

With regard to the dangerous formation of vapour in the brake cylinder, it is very difficult to determine the exact relation between the thermal absorption capacity of brake fluids of varying composition and the brake performance realised out of different driving situations. Therefore, certain safety thresholds are derived from empirical values and the thermal reserve is defined as follows:-

$$\text{THERMAL RESERVE} \approx (T_{permissible} - T_{actual})$$

In this definition, $T_{permissible}$ is a yet permissible limit temperature of a brake fluid and

T_{actual} is the momentary temperature of the brake fluid reached during the braking operation.

If the THERMAL RESERVE drops below a value derived from experience then the THERMAL RESERVE is used up. This will be signalled to the driver. By treating the brake gently or by taking other measures for cooling down the brake fluid the driver then may counteract the danger of a formation of vapour bubbles. If the thermal reserve is used up as early as in case of relatively sparse brake application this permits the conclusion that there is a trouble in the brake system or that the brake fluid has aged excessively.

The two circuit configurations of Figures 2 and 3 serve to explain different measuring principles within the scope of this invention. Both circuit configurations are provided for checking the brake fluid in an automotive vehicle's brake sytem.

When using the circuit configuration of Figure 2 the process sequence is initiated at certain time intervals - for instance, each time that the ignition switch 8 of an automotive vehicle's engine is actuated. The signal released by the switch 8 is fed to a sequencing control and logic 9 which may contain hardwired circuits or a program-controlled circuit such as a microcomputer. At first a measurement is performed in the hot mode. To this end, the circuit 9 is equipped with a mode selector circuit 10 ("MODE SELECT"). The signal of circuit 10 switches on a generator 11 and simultaneously brings a

switch 12 into the WM (= HM = hot mode) position. The generator 11 generates an alternating current of constant amplitude. In practise, such a generator is realised by means of, e.g., a power operational amplifier, or rather by an operational amplifier followed by a power transistor operated as a voltage-controlled current source. By switching over the voltage levels at the input of the generator 11 by means of the sequencing control 9 the operating currents are generated for implementing the measurements in the hot and cold modes. In one example of an embodiment of this invention, 700 milliamperes are provided for the hot mode measurements and 7 milliamperes are provided for the cold mode.

The current source, namely the generator 11, supplies a sensor element 13 having the design of one of the sensor elements 1 to 5 represented in Figure 1. By using alternating current, undesired electrolytic effects are prevented which might lead to the deterioration of the fluid to be measured.

The output signal of the sensor 13 is handled in a subsequent rectifier-and-filter stage 14. The measured signal obtained in the hot mode is stored in a memory 15 until a subsequent hot mode measurement.

Subsequently, the selector circuit 10 switches back the switch 12 into the KM (=CM = cold mode) position and switches back the generator 11 which now only emits a very low current needed for the cold mode measurment. In a differential amplifier stage 16 the signal measured in

the cold mode is continuously subtracted from the memory's 15 output signal representing the hot-mode-measured result and in a comparator 17 the difference signal is compared with a reference signal generated in the source 18. The reference signal, or rather the output signal of the stage 18, is a measure for the minimal thermal reserve to be maintained for safety reasons. If there is a drop below said minimum value a warning signal is given by means of the logic 9 and by means of an indicating unit 19.

In the embodiment illustrated, the output signal of the reference stage 18 is also used for checking the signal generated in the cold mode. To this end, a comparator 20 is provided. If the sensor element 13 is intact the KM signal must move within a certain "window". This is checked by the comparator 20 whose output signal is likewise supplied to the logic 9 and may cause a trouble to be indicated or a warning to be displayed in the indicating unit 19.

In practise, the assemblies 11,12,13,14 can be realised most easily by analogous units while the digital technique is applicable to the functions of the stages 15,16,17,18,20. The use of a corresponding programmed micro-computer is likewise suitable.

It is also possible to release the sequence control - in particular the cold mode measurements - only after the brake has been applied. This is expressed by the symbolic illustration of a brake pedal 21 signalling a

brake application to the sequencing control 9.

In contrast to the sequence described with reference to Figure 2, in the embodiment of the circuit shown in Figure 3, the signals obtained in hot mode and in cold mode are processed in parallel. In this example, the output of a sequencing control and logic 22 leads to a generator 23 simultaneously generating the alternating currents needed in hot mode and in cold mode. Via parallel signal paths I, II each equipped with their own sensor elements 24 and 25 and susequent signal processing stages 26 and 27 (rectifier-and-filter circuits), the measured signals can be generated and processed in parallel in the hot mode (branch I) and in the cold mode (branch II). In a differential amplifier stage 28 then the measured results are compared and the thermal reserve is formed whose minimum value again is predetermined by a stage 29 generating a reference signal. Via comparator stages 30,31, the reference signal is combined with the difference signal (output signal of the amplifier 28) and with the measured signal obtained in the cold mode. The output signals of the comparators 30,31 are supplied to the sequencing control and logic 22. An indicating unit is connected 32, on its part, to the sequencing control and logic 22. Troubles in the system as well as the fact that the minimum thermal reserve has been reached cause a warning to be displayed via the indicating unit 32.

When the brake is applied, an actuating signal is supplied by the brake pedal 33 to the sequencing control

22 since, in general, it is sufficient to carry out the measurements, or rather the determination of the thermal reserve, during a braking operation, only.

For implementing the sequence described with reference to Figure 3, in many cases it should be sufficient to accommodate the sensor element 24 for the determination of the hot mode in the usual pressure medium storage/pressure compensation reservoir of a brake system while the sensor element(s) 25 for measuring the momentary fluid temperature expediently are to be arranged in the wheel brakes of the wheels stressed most.

It is likewise possible to combine the modes of operation of the circuit configuration of Figures 2 and 3.

CLAIMS

1. A method for determining and.or checking the state or the condition of a fluid contained in a hydraulic system, in which method the boiling point, or a characteristic value depending on the boiling point, is determined by means of sensor elements, characterised in that the momentary state and/or the momentary stress on the fluid is measured and compared with the characteristic value, a so-called (momentary) thermal reserve is thence determined which constitutes a measure for the further stressability, in particular for the permissible further heating, of the fluid and in that the reaching of a predetermined minimum value of the thermal reserve is indicated.

2. A method as claimed in claim 1, characterised in that, at predetermined intervals, the characteristic value is determined and stored in a memory (15) and that the momentary temperature of the fluid is compared with the last-stored characteristic value so as to determine the thermal reserve.

3. A method as claimed in claim 1 or 2 and applied to the checking of the state of the brake fluid contained in an automotive vehicle's brake system, characterised in that, upon the starting of the vehicle's engine, the characteristic value is determined and stored by means of a measuring device stationed in the automotive vehicle and in that, upon application of the brake, the stored measured values are compared with the momentary

temperature of the brake fluid so as to form the thermal reserve.

4. A method as claimed in claim 1 or 2 and applied to the checking of the state of a brake fluid contained in an automotive vehicle's brake system, characterised in that, during a braking operation, the characteristic value and the momentary temperature of the brake fluid are measured alternatingly by means of a measuring device stationed in the vehicle and in that, for forming the thermal reserve, the measured values are compared.

5. A device for implementing the method as claimed in any one of claims 1 to 4, characterised in that the device comprises a measuring device for determining the boiling temperature of the fluid, or rather a characteristic value depending on the boiling temperature, which measuring device is associated with the hydraulic system and is stationed in a vehicle, temperature-measuring elements (25) for determining the momentary temperature of the fluid, electronic circuits for handling and processing the measured signals as well as for storing the characteristic values determined last and for determining a momentary thermal reserve derived from the difference of the measured values, and indicating units (19,32) for signalling a sufficient and/or an insufficient thermal reserve.

6. A device as claimed in claim 5, characterised in that the measuring device for determining the boiling point, or the characteristic value depending on the

boiling point, is equipped with one or more sensor elements (1 - 5,13,24) arranged in the fluid.

7. A device as claimed in claim 6, characterised in that the sensor elements (1 - 5,13,24) for determining the boiling point, or the characteristic value, are capable of being heated up.

8. A device as claimed in claim 5 or 6, characterised in that the sensor elements have hollow spaces with open, pierced walls and are so designed as to ensure that, after heating-up to a temperature within a range lying below the boiling temperature, there is established a stable cellular convection which is evaluable as a criterion of the state and/or the condition of the fluid.

9. A device as claimed in claim 8, characterised in that the sensor elements are designed in the form of hollow coils (1 - 4), perforated tubes or hollow bodies (5) limited by grid-or-net-shaped boundary surfaces.

10. A device as claimed in any one of claims 6 to 9, characterised in that the momentary temperature of the fluid can be ascertained by measuring the temperature-dependent electrical resistance of the sensor elements (1 - 5,13,24,25(4).

11. A device as claimed in any one of claims 6 to 10, characterised in that the sensor elements (1 - 5,13,24,25) for heating up the fluid and/or for measuring the temperature of the fluid are supplied with alternating current.

12. A device as claimed in any one of claims 6 to 11, for checking the brake fluid contained in a vehicle brake system, characterised in that the sensor elements (1-5,13,24,25) for determining the momentary temperature of the fluid and/or the characteristic value depending on the boiling temperature are arranged in the wheel brakes or in the proximity of the wheel brakes.

13. A device for checking the brake fluid contained in a vehicle brake system, as claimed in any one of claims 6 to 11, characterised in that sensor elements (1 - 5,13,25) for determining the momentary temperature are arranged in the individual wheel brake cylinders or in the proximity thereof and in that sensor elements (1 - 5,13,24) for determining the characteristic value depending on the boiling temperature of the fluid are arranged in a central location such as in the pressure medium storage reservoir of the brake system.

14. A device as claimed in any one of claims 6 to 11, characterised in that the same sensor elements (1 - 5,13) are used both for determining the characteristic value depending on the boiling temperature and for measuring the momentary temperature.

15. A circuit configuration for controlling the device as claimed in any one of claims 5 to 14, and used for checking the brake fluid, contained in a vehicle's brake system, characterised in that, upon the starting of the vehicle's engine, the circuit configuration measures the boiling temperature of the brake fluid. or a

characteristic value depending on the boiling temperature, and stores that value until a new starting of the engine and in that, during the application of the brake, the circuit configuration, by means of the same sensor elements (1 - 5,13), determines the momentary temperature of the fluid and compares it with the stored measured value so as to form the thermal reserve.

16. A circuit configuration for controlling the device as claimed in any one of claims 5 to 14, and used for checking the brake fluid contained in a vehicle's brake system, characterised in that, upon the application of the brake pedal (21), the circuit configuration, by means of the same sensor elements (1 - 5,13), alternatingly determines the boiling temperature of the fluid, or the characteristic value, as well as the momentary temperature of the brake fluid and compares the successively obtained measured values so as to form the thermal reserve.

17. A method for determining and/or checking the state or the condition of a fluid contained in a hydraulic system substantially as describerd with reference to the accompanying drawings.

18. A device for implementing the method claimed in claim 17 substantially as described with reference to the accompanying drawings.

19. A circuit configuration for controlling the device claimed in claim 18 substantially as described with reference to Figure 2 or 3 of the accompanying drawings.